vitiated by too many subdivisions. These subdivisions are dealt with in the introduction, where a bewildering scheme of classification is proposed "in order to ascertain the opinion of anthropologists as to its merits." First the science is grouped under three main heads, indicated by terminations furnished by the three Greek words, *γράφη*, *λόγος*, and *νόμος*. Then each group is split up into thirteen minor divisions, yielding altogether thirty-nine distinct segmentations, and of course involving the whole subject in dire confusion. The student is expected, for instance, to distinguish between anthropography, anthropology, and anthroponomy; between pneumatography, pneumatology, and pneumatonomy; between hexiography, hexiology, hexionomy, and so on. However in the bibliography the author considerately limits himself to eleven headings, which will certainly be amply sufficient to try the patience of those who may have occasion to consult these alphabetical lists. Thus Nesbit's "Antiquity of Man" is entered under *Anthropogeny*, while Ameghino's "Antiquedad del hombre in La Plata" must be sought for in the section *Archæology*. These lists should obviously be fused together in one general catalogue, and all the nice subdivisions left to the fancy or ingenuity of the reader. To show their utter absurdity it may suffice to add that under the heading *Hexiology* there occurs the solitary entry—Buckley, "Climatic Influences on Mankind." Why, it may be asked in conclusion, does B. B. Redding's "Californian Indians and their Food," appear in the section *Technology?* The interests of science are not furthered by these minute subdivisions and barbarous nomenclatures, which are especially uncalled for in the case of a science whose broad divisions are already marked out with sufficient clearness and accuracy to serve all present practical purposes.

Prof. Mason has been much more usefully employed in the preparation of a series of "Miscellaneous Papers Relating to Anthropology," which also consist of reprints from the Smithsonian Report for 1881. Most of them have reference to the sepulchral mounds, earthworks, fortified lines, shell-heaps, and other remains of prehistoric and historic man so thickly strewn over the Mississippi basin, the eastern States and seaboard of North America. The great number and magnitude of these remains, their universal diffusion over an enormous area, and the character of the objects found in them, all tend to confirm the impression now generally entertained regarding the vast antiquity of man in the New World. On the other hand the views of those anthropologists who still attribute the old works to some superior pre-Columbian race of "mound-builders" distinct from the present aborigines are not strengthened by a more careful examination of these relics. Speaking of the mounds examined by him in Cass County, Illinois, Dr. J. F. Snyder remarks that "the intrinsic evidence of many prehistoric remains of this county sustains their claim to extreme antiquity; but no work or specimen of art of a former race has yet been found here above the capacity or achievement of the typical North American Indian. And in studying the life, habits, and burial customs indicated by these relics, I can see no necessity for ascribing them to the agency of a distinct or superior race, when they express so unmistakably the known status of Indian intellect" (p. 53). This conclusion is amply confirmed by the contents of the enormous shell-heap at Cedar Keys, Florida, which has been carefully examined by Mr. S. T. Walker. Here the pottery found in the successive layers, down to a depth of over twelve feet, shows a continuous advancement in the art from the rude heavy earthenware often mixed with coarse sand or small pebbles occurring in the lowest stratum, through the better finished and slightly ornamented types of the middle stage, to the delicate and beautifully ornamented specimens found near the surface. These objects thus show a progressive improvement *upwards*, not *downwards* as would be required by the theory of an extinct pre-Columbian civilised race, precursor of the present aborigines.

A. H. K.

THE SIZE OF ATOMS[1]

III.

WE must then find another explanation of dispersion. I believe there is another explanation. I believe that, while giving up Cauchy's unmodified theory of dispersion, we shall find that the same general principle is applicable, and that by imagining each molecule to be loaded in a certain definite way by elastic connection with heavier matter,—each molecule of the ether to have, in palpable transparent matter, a small fringe, so to speak, of particles, larger and larger in their successive order, elastically connected with it,—we shall have a rude mechanical explanation, realisable by the notably easy addition of the proper appliances to the dynamical models before you, to account for refractive dispersion in an infinitely fine-grained structure. It is not 17 hours since I saw the possibility of this explanation; I think I now see it perfectly, but you will excuse me not going into the theory more fully under the circumstances.[2] The difficulty of Cauchy's theory has weighed heavily upon me, when thinking of bringing this subject before you. I could not bring it before you and say there are only four particles in the wave-length, and I could not bring it before you without saying there is some other explanation. I believe another explanation is distinctly to be had in the manner I have slightly indicated.

Now look at those beautiful distributions of colour on the screen before you. They are diffraction spectrums from a piece of glass ruled with 2,000 lines to the inch. And again look; and you see one diffraction spectrum by reflection from one of Rutherford's gratings, in which there are 17,000 lines to the inch on polished speculum-metal. The explanation by "interference", is substantially the same as that which the undulatory theory gives for Newton's rings of light reflected from the two surfaces, which you have already seen. Where light-waves from the apertures between the successive bars of the grating, reach the screen in the same phase, they produce light; there, again, where they are in opposite phases, they produce darkness

The beautiful colours which are produced, depend on the places of conspiring and opposing vibrations on the screen, being different for light waves of different wave-lengths; and it is by the measurements of the dimensions of a diffraction spectrum such as the first set you saw (or of finer spectrums from coarser gratings), that Fraunhofer first determined the wave-lengths of the different colours.

I have now, closely bearing on the question of the size of atoms, thanks to Dr. Tyndall, a most beautiful and interesting experiment to show you—the artificial "blue sky," produced by a very wonderful effect of light upon matter, which he discovered. We have here an empty glass tube—it is "optically void." A beam of electric light passes through it now; and you see nothing. Now the light is stopped and we admit vapour of carbon disulphide into the tube. There is now introduced some of this vapour to about 3 inches pressure, and there is also introduced, to the amount of 15 inches pressure, air impregnated with a little nitric acid, making in all rather less than the atmospheric pressure. What is to be illustrated here is the presence of molecules of substances, produced by the decomposition of carbon disulphide by the light.

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[1] A lecture delivered by Sir William Thomson at the Royal Institution, on Friday, February 2. Revised by the Author. Concluded from p. 254.

[2] Farther examination has seemed to me to confirm this first impression; and in a paper on the Dynamical Theory of Dispersion, read before the Royal Society of Edinburgh, on the 5th of March, I have given a mathematical investigation of the subject.—W. T., March 16, 1883.

At present you see nothing in the tube; it still continues to be, as before the admission of the vapours optically transparent; but gradually you will see an exquisite blue cloud. That is Tyndall's "blue sky." You see it now. I take a Nicol's prism, and by looking through it I find the azure light, coming from the vapours in any direction perpendicular to the exciting beam of light, to be very completely polarised in the plane through my eye and the exciting beam. It consists of light-vibrations in one definite direction, and that, as finally demonstrated by Professor Stokes, it seems to me beyond all doubt, through reasoning on this phenomenon of polarisation,[1] which he had observed in various experimental arrangements giving minute solid or liquid particles scattered through a transparent medium, must be the direction perpendicular to the plane of polarisation.

What you are now about to see, and what I tell you I have seen through the Nicol's prism, is due to what I may call secondary or derived waves of light diverging from very minute liquid spherules, condensed in consequence of the chemical decomposing influence exerted by the beam of light on the matter in the tube, which was all gaseous when the light was first admitted.

To understand these derived waves, first you must regard them as due to motion of the ether round each spherule; the spherule being almost absolutely fixed, because its density is enormously greater than that of the ether surrounding it. The motion that the ether had in virtue of the exciting beam of light alone, before the spherules came into existence, may be regarded as being compounded with the motion of the ether relatively to each spherule, to produce the whole resultant motion experienced by the ether when the beam of light passes along the tube, and azure light is seen proceeding from it laterally. Now this second component motion, is clearly the same as the whole motion of the ether would be, if the exciting light were annulled and each spherule kept vibrating in the opposite direction, to and fro through the same range as that which the ether in its place had, in virtue of the exciting light, when the spherule was not there.

Supposing now, for a moment, that without any exciting beam at all, a large number of minute spherules are all kept vibrating through very small ranges[2] parallel to one line. If you place your eye in the plane through the length of the tube and perpendicular to that line, you will see light from all parts of the tube, and this light which you see will consist of vibrations parallel to that line. But if you place your eye *in* the line of the vibration of a spherule, situated about the middle of the tube, you will see no light in that direction; but keeping your eye in the same position, if you look obliquely towards either end of the tube, you will see light fading into darkness, as you turn your eye from either end towards the middle. Hence, if the exciting beam be of plane polarised light—that is to say, light of which all the vibrations are parallel to one line—and if you look at the tube in the direction perpendicular to this line and to the length of the tube, you will see light of which the vibrations will be parallel to that same line. But if you look at the tube in any direction parallel to this line, you will see no light; and the line along which you see no light is the direction of the vibrations in the exciting beam; and this direction, as we now see, is the direction perpendicular to what is technically called the plane of polarisation of the light. Here, then, you have Stokes's *experimentum crucis* by which he has answered, as seems to me beyond all doubt, the old vexed question—Whether is the vibration *perpendicular to*, or *in* the plane of polarisation? To show you this experiment, instead of using unpolarised light for the exciting beam, as in the previous experiment, and holding a small Nicol's prism in my hand and telling you what I saw when I looked through it, I place, as is now done, this great Nicol's prism in the course of the beam of light before it enters the tube. I now turn the Nicol's prism into different directions and turn the apparatus round, so that, sitting in all parts of the theatre, you may all see the tube in the proper direction for the successive phenomena of "light," and "no light." You see them now exactly fulfilling the description which I gave you in anticipation. If each of you had a Nicol's

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[1] Extract from Professor Stokes' paper, "On the Change of Refrangibility of Light," read before the Royal Society, May 27th, 1852, and published in the *Transactions* for that date:—

"§ 183. Now this result appears to me to have no remote bearing on the
"question of the direction of the vibrations in polarised light. So long as
"the suspended particles are large compared with the waves of light, reflection
"takes place as it would from a portion of the surface of a large solid immersed
"in the fluid, and no conclusion can be drawn either way. But if the diameters
"of the particles be small compared with the length of a wave of light, it
"seems plain that the vibrations in a reflected ray cannot be perpendicular
"to the vibrations in the incident ray. Let us suppose for the present, that
"in the case of the beams actually observed, the suspended particles were
"small compared with the length of a wave of light. Observation showed
"that the reflected ray was polarised. Now all the appearances presented
"by a plane polarised ray are symmetrical with respect to the plane of
"polarisation. Hence we have two directions to choose between for the
"direction of the vibrations in the reflected ray, namely, that of the incident
"ray, and a direction perpendicular to both the incident and the reflected
"rays. The former would be necessarily perpendicular to the directions of
"vibration in the incident ray, and therefore we are obliged to choose the
"latter, and consequently to suppose that the vibrations of plane polarised
"light are perpendicular to the plane of polarisation, since experiment shows
"that the plane of polarisation of the reflected ray is the plane of reflection.
"According to this theory, if we resolve the vibrations in the [horizontal]
"incident ray horizontally and vertically, the resolved parts will correspond
"to the two rays, polarised respectively in and perpendicularly to the plane of
"reflection, into which the incident ray may be conceived to be divided, and
"of these the former alone is capable of furnishing a . . . . . ray reflected
"vertically upwards [to be seen by an eye above the line of the incident ray,
"and looking vertically downwards]. And, in fact, observation shows that,
"in order to quench the dispersed beam, it is sufficient, instead of analysing
"the reflected light, to polarise the incident light in a plane perpendicular to
"the plane of reflection."

[2] In the following question of the recent Smith's Prize Examination at Cambridge (paper of Tuesday, Jan. 30, 1883), the dynamics of the subject, and particularly the motion of the ether produced by keeping a single spherule embedded in it vibrating to and fro in a straight line, are illustrated in parts (*a*) and (*d*):—

"8. (*a*) From the known phenomenon that the light of a cloudless blue
"sky, viewed in any direction perpendicular to the sun's direction, is almost
"wholly polarised in the plane through the sun, assuming that this light is
"due to particles of matter of diameters small in comparison with the wave-
"length of light, prove that the direction of the vibrations of plane polarised
"light is perpendicular to the plane of polarisation.

"(*b*) Show that the equations of motion of a homogeneous isotropic elastic
"solid of unit density, are

$$\frac{d^2\alpha}{dt^2} = (k + \tfrac{1}{3}n)\frac{d\delta}{dx} + n\nabla^2\alpha,$$

$$\frac{d^2\beta}{dt^2} = (k + \tfrac{1}{3}n)\frac{d\delta}{dy} + n\nabla^2\beta,$$

$$\frac{d^2\gamma}{dt^2} = (k + \tfrac{1}{3}n)\frac{d\delta}{dz} + n\nabla^2\gamma,$$

"where k denotes the modulus of resistance to compression; n the rigidity-
"modulus; α, β, γ the components of displacement at (x, y, z, t); and

$$\delta = \frac{d\alpha}{dx} + \frac{d\beta}{dy} + \frac{d\gamma}{dz},$$

$$\nabla^2 = \frac{a^2}{dx^2} + \frac{d^2}{dy^2} + \frac{d^2}{dz^2}.$$

"(*c*) Show that every possible solution is included in the following:

$$\alpha = \frac{d\phi}{dx} + u, \quad \beta = \frac{d\phi}{dy} + v, \quad \gamma = \frac{d\phi}{dz} + w,$$

"where u, v, w are such that

$$\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz} = 0.$$

"Find differential equations for the determination of ϕ, u, v, w. Find
"the respective wave-velocities for the ϕ-solution, and for the (u, v, w)-
"solution.

"(*d*) Prove the following to be solutions, and interpret each for values o
"$r\,[\sqrt{(x^2 + y^2 + z^2)}]$ very great in comparison with λ (the wave-length).

$$(1)\quad \begin{cases} \alpha = \dfrac{d\phi}{dx}, \quad \beta = \dfrac{d\phi}{dy}, \quad \gamma = \dfrac{d\phi}{dz} \\ \text{where } \phi = \dfrac{1}{r}\sin\dfrac{2\pi}{\lambda}\left[r - t\sqrt{(k + \tfrac{4}{3}n)}\right]. \end{cases}$$

$$(2)\quad \begin{cases} \alpha = 0, \quad \beta = -\dfrac{d\psi}{dz}, \quad \gamma = \dfrac{d\psi}{dy} \\ \text{where } \psi = \dfrac{1}{r}\sin\dfrac{2\pi}{\lambda}\left[r - t\sqrt{n}\right]. \end{cases}$$

$$(3)\quad \alpha = \left(\frac{2\pi}{\lambda}\right)^2\psi + \frac{d^2\psi}{dx^2}, \quad \beta = \frac{d^2\psi}{dx\,dy}, \quad \gamma = \frac{d^2\psi}{dx\,dz}.$$

prism in your hand, you would learn that when you see light at all, its plane of polarisation is in the plane through your eye and the axis of the tube; and I hope you all now perfectly understand the proof that the direction of vibration is perpendicular to this plane.

Now I want to bring before you something which was taught me a long time ago by Professor Stokes; and year after year I have begged him to publish it, but he has not done so, and so I have asked him to allow me to speak of it to-night. It is a dynamical explanation of that wonderful phenomenon called fluorescence or phosphorescence. The principle is mechanically represented by this model (described above with reference to Fig. 2). A simple harmonic motion is, as you now see, sustained by my hand in the uppermost bar, in a period of about four seconds. You see that a regular wave-motion travels down the line of molecules represented by these circular disks on the ends of the bars; and the energy continually given to the top bar, by my hand, is continually consumed in heating the basin of treacle and water at the foot. I now remove my hand and leave the whole system to itself. The very considerable sum of kinetic and potential energies of the large masses and spiral springs, attached to the top bar, is gradually spent in sending the diminishing series of waves down the line, and is ultimately converted into heat in the treacle and water. You see that about half of the amplitude of vibration, and therefore three-fourths of the energy is lost in half a minute.

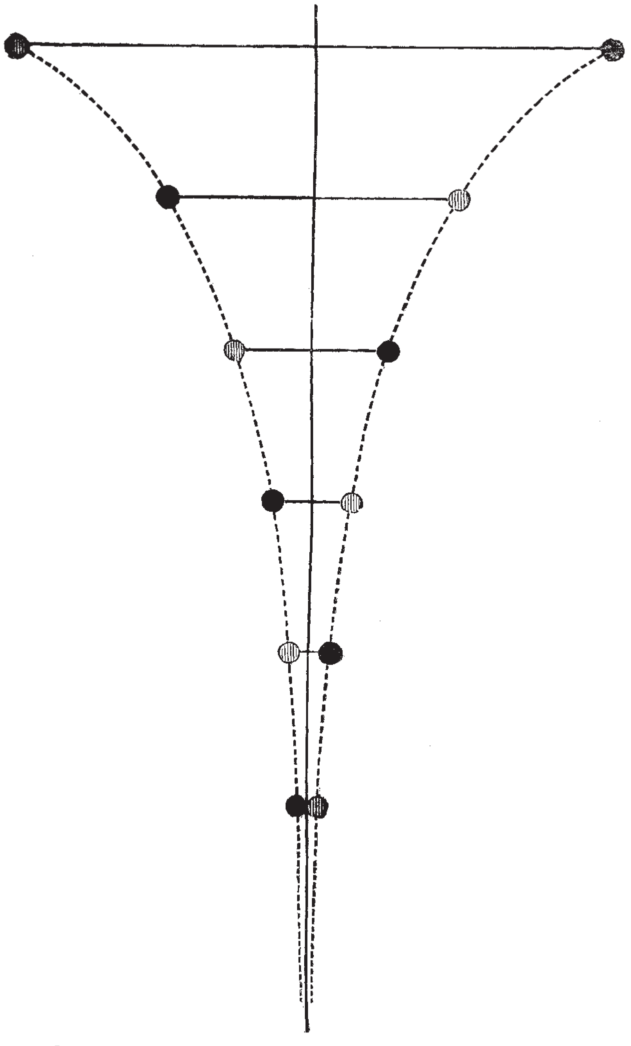

FIG. 10.—Diagram showing the different amplitudes of vibration of a row of particles oscillating in a period less than their least wave-period.

You will see on quickening the oscillation how very different the result will be. The quick oscillations which I now give to the top bar (the period having been reduced to about one and a half seconds), is incapable of sending waves along the line of molecules; and it is that rapid oscillation of the particles which, according to Stokes, constitutes latent or stored-up light. Remark now that when I remove my hand from the top bar, as no waves travel down the line, no energy is spent in the treacle; and the vibration goes on for ever (or, to be more exact, say for one minute) as you see, with *no loss* (or, to be quite in accordance with what we see, let me say scarcely any sensible loss). This is a mechanical model correctly illustrating the dynamical principle of Stokes' explanation of phosphorescence or stored-up light, stored as in the now well-known luminous paint; of which you see the action in this specimen, and in the phosphorescent sulphides of lime in these glass tubes kindly lent by Mr. De La Rue. (Experiments shown.)

Now I will show you Stokes' phenomenon of *fluorescence* in a piece of uranium glass. I hold it in the beam from the electric lamp dispersed by the prism as you see. You see the uranium glass now visible by being illuminated by invisible rays. The rays by which it is illuminated even before it comes into the visible rays are manifestly invisible so far as the screen receiving the spectrum is a test of visibility; because the uranium glass, and my hands holding it, throw no shadow on the screen. Also you see the uranium glass which I hold in my hand in the ultra-violet light, while you do not see my hand. I now bring it nearer the place where you see the air (or rather the dust in it) illuminated by the violet light: still no shadow on the screen, but the uranium glass in my hand glowing more brilliantly with its green light of very mixed constitution, consisting of waves of longer periods than that of the ultra-violet, which the incident light, of shorter period than that of violet light, causes the particles of the uranium glass to emit. This light is altogether unpolarised. It was the absolute want of polarisation, and the fact of its periods being all less than those of the exciting light, that led Stokes to distinguish this illumination, which you see in the uranium glass,[1] from the mere molecular illumination (always polarised partially if not completely, and always of the same period as that of the exciting light) which we were looking at previously in Dr. Tyndall's experiment.

Stokes gave the name of fluorescence to the glowing with light of larger period than the exciting light, because it is observed in fluor spar; and he wished to avoid all hypothesis in his choice of a name. He pointed out a strong resemblance between it and the old known phenomenon of phosphorescence; but he found some seeming contrasts between the two, which prevented him from concluding fluorescence to be in reality a case of phosphorescence.

In the course of a comparison between the two phenomena (sections 221 to 225 of his 1852 paper), the following statement is given:—"But by far the most "striking point of contrast between the two phenomena "consists in the apparently instantaneous commencement "and cessation of the illumination, in the case of internal "dispersion when the active light is admitted and cut "off. There is nothing to create the least suspicion of "any appreciable duration in the effect. When internal "dispersion is exhibited by means of an electric spark, it "appears no less momentary than the illumination of a "landscape by a flash of lightning. I have not attempted "to determine whether any appreciable duration could "be made out by means of a revolving mirror." The investigation here suggested, has been actually made by Edmund Becquerel, and the question—Is there any appreciable duration in the glow of fluorescence?—has been answered affirmatively by this beautiful and simple little machine before you, which he invented for the purpose. The experiment giving the answer is most interesting, and I am sure you will see it with pleasure. It consists of a flat circular box, with two holes facing one another in the flat sides near the circumference; inside are two disks, carried by a rapidly revolving shaft, by which the holes are alternately shut and opened; one open when the other is closed, and *vice versâ*. A little piece of uranium glass is fixed inside the box between the two holes, and a beam of light from the electric lamp falls upon one of the holes. You look at the other.

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[1] The same phenomenon is to be seen splendidly in sulphate of quinine An interesting experiment may be made by writing on a white paper screen, with a finger or a brush dipped in a solution of sulphate of quinine. The marking is quite imperceptible in ordinary light; but if a prismatic spectrum be thrown on the screen, with the ultra-violet invisible light on the part which had been written on with the sulphate of quinine, the writing is seen glowing brilliantly with a bluish light, and darkness all round. The phenomenon presented by sulphate of quinine and many other vegetable solutions, and some minerals as, for instance, fluor spar, and various ornamental glasses, as a yellow Bohemian glass, called in commerce "canary glass" (giving a dispersed greenish light), had been discovered by Sir David Brewster (*Transactions*, Royal Society of Edinburgh, 1833, and British Association, Newcastle, 1838), and had been investigated also by Sir John Herschel, and by him called "epipolic dispersion" (*Phil. Trans.*, 1845). A complete experimental analysis of the phenomenon, showing precisely what it was that the previous observers had seen, and explaining many singularly mysterious things which they had noticed, was made by Stokes, and described in his paper, "On the Change of Refrangibility of Light" (*Phil. Trans.*, May 27, 1852).

Now when I turn the shaft slowly you see nothing. At this instant the light falls on the uranium glass through the open hole far from you, but you see nothing, because the hole next you is shut. Now the hole next you is open, but you see nothing; because the hole next the light is shut, and the uranium glass shows no perceptible after-glow as arising from its previous illumination. This agrees exactly with what you saw when I held the large slab of uranium glass in the ultra-violet light of the prismatic spectrum. As long as I held the uranium glass there you saw it glowing; the moment I took it out of the invisible light it ceased to glow. The "moment" of which we were then cognisant, may have been the tenth of a second. If the uranium glass had continued to glow sensibly for the twentieth or the fiftieth of a second, it would have seemed, to our slow-going sense of vision, to cease the moment it was taken out. Now I turn the wheel at such a rate that the hole next you is open about a fiftieth of a second after the uranium glass was bathed in light; still you see nothing. I turn it faster and faster and it now begins to glow, when the hole next you is open about the two-hundredth of a second after the immediately preceding admission of light by the other hole. I turn it faster and faster and it glows more and more brightly, till now it is glowing like a red coal; further augmentation of the speed shows, as you see, but little difference in the glow.

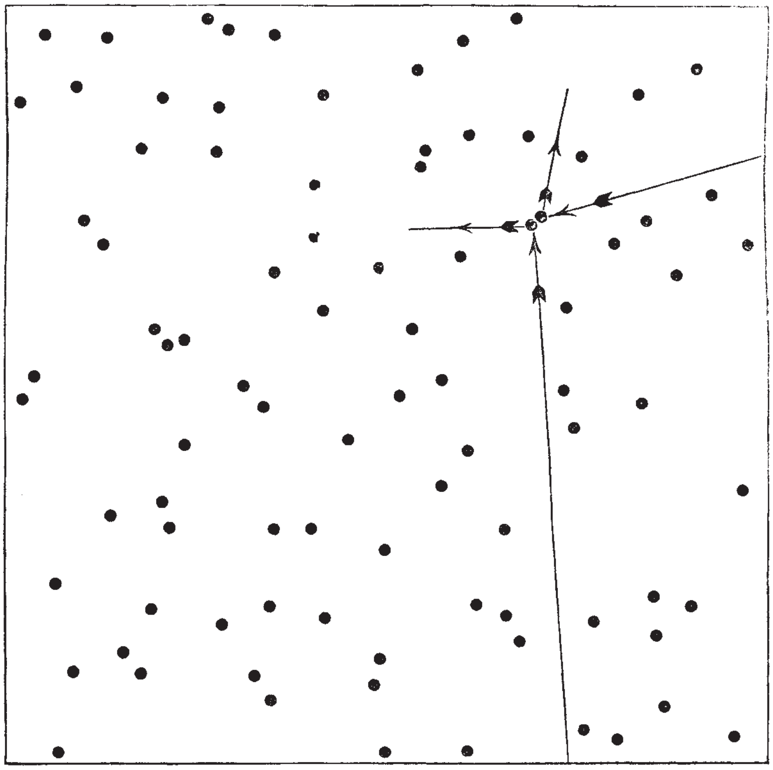

FIG. 11.—Diagram illustrating the number of molecules in a space of 1/10,000 of a centimetre square and 1/100,000,000 of a centimetre thick.

Thus it seems that fluorescence is essentially the same as phosphorescence; and we may expect that substances will be found, continuously bridging over the difference of quality between this uranium glass, which glows only for a few thousandths of a second, and the luminous sulphides which glow for hours, or days, or weeks after the cessation of the exciting light.

The most decisive and discriminating method of estimating the size of atoms, I have left until my allotted hour is gone:—that founded on the kinetic theory of gases. Here is a diagram (Fig. 11) of a crowd of atoms or molecules showing, on a scale of 1,000,000 to 1, all the molecules of air, of which the centres may, at any instant, be in a space of a square of 1/10,000 of a centimetre side and 1/100,000,000 of a centimetre thick. The side of the square you see in the diagram is a metre, and represents 1/10,000 of a centimetre. The diagram shows just 100 molecules, being 1/10,000 of the whole number of particles (10^6) in the cube of 1/10,000 centimetre, or all the molecules in a slice of 1/10,000 of the thickness of that cube. Think of a cube filled with particles, like these glass balls,[1] scattered at random through a space equal to 1,000 times the sum of their volumes. Such a crowd may be condensed (just as air may be condensed) to 1/1,000 of its volume; but this condensation brings the molecules into contact. Something comparable with this may be imagined to be the condition of common air of ordinary density, as in our atmosphere. The diagram with size of each molecule, which, if shown in it to scale, would be 1 millimetre (or too small to be seen by you), to represent an actual diameter 1/10,000,000 of a centimetre, represents a gas in which a condensation of 1 to 10 linear, or 1 to 1,000 in bulk, would bring the molecules close together.

Now you are to imagine the particles moving in all directions, each in a straight line until it collides with another. The average length of free path is ten centimetres in our diagram, representing 1/100,000 of a centimetre in reality. And to suit the case of atmospheric air of ordinary density and at ordinary pressure, you must suppose the actual velocity of each particle to be 50,000 centimetres per second; which will make the average time from collision to collision 1/5,000,000,000 of a second.

The time is so far advanced that I cannot speak of the details of this exquisite kinetic theory, but I will just say that three points investigated by Maxwell and Clausius—viz. the viscosity, or want of perfect fluidity of gases; the diffusion of gases into one another; and the diffusion of heat through gases—all these put together give an estimate for the average length of the free path of a molecule. Then a beautiful theory of Clausius enables us from the average length of the free path to calculate the magnitude of the atom. That is what Loschmidt has done,[2] and I, unconsciously following in his wake, have come to the same conclusion; that is, we have arrived at the absolute certainty that the dimensions of a molecule of air is something like that which I have stated.

The four lines of argument which I have now indicated, lead all to substantially the same estimate of the dimensions of molecular structure. Jointly they establish, with what we cannot but regard as a very high degree of probability, the conclusion that, in any ordinary liquid, transparent solid, or seemingly opaque solid, the mean distance between the centres of contiguous molecules is less than the 1/5,000,000, and greater than the 1/1,000,000,000 of a centimetre.

To form some conception of the degree of coarse-grainedness indicated by this conclusion, imagine a globe of water or glass, as large as a football,[3] to be magnified up to the size of the earth, each constituent molecule being magnified in the same proportion. The magnified structure would be more coarse-grained than a heap of small shot, but probably less coarse-grained than a heap of footballs.

SMOKE ABATEMENT

An important meeting was held in the Egyptian Hall of the Mansion House on Monday last, to take further steps towards the abolition, or at all events the reduction, as far as possible, of the smoke nuisance. The Lord Mayor presided, and the following among others were present:—The Duke of Northumberland, the Duke and Duchess of Westminster, Sir William Siemens, Sir Frederick Abel, Sir Lyon Playfair, M.P., Sir Frederick Pollock, Sir T. Spencer Wells, Mr. George Cubitt, M.P., Dr. Farquharson, M.P., Col. Makins, M.P., Capt. Galton, Mr. Edwin Chadwick, C.B., Mr. Ernest Hart, Mr. C. Waring, the Hon. Rollo Russell, General Lowry, C.B., Mr. George Shaw (chairman of the City Commission of Sewers), Mr. W. R. E. Coles, Mr. W. Chandler Roberts, of the Royal Mint, and Mr. Gregory, Master of the Clothworkers' Company.

The proceedings were opened by the reading of a Report, which has been carefully prepared by the Council, detailing the steps which have already been taken, and giving particulars of the exhibitions of last year in London and Manchester. The Report also deals with the work which has been done regarding the chemical composition of smoke by Prof. Chandler Roberts, and the many tests of coal made by Mr. Clark. In this important investigation, attention was called to the fact that a very great discrepancy exists between the heating efficiency of various types of grates, stoves, furnaces, and the like. In some forms of grate, for instance, only 22 per cent. of the total heat is utilised, whilst others require nearly three tons of coal to do the same work which other stoves manage to get out of one ton.

The Council desired to report that, so far as they had been able to ascertain, the most marked benefit resulting from the movement had been in the increased use of gas and coke for heating purposes. The improvement in gas-heating apparatus had been considerable, and the use of coke had been greatly facilitated by its being supplied to the public in more convenient sizes than formerly, and by the introduction of firebrick or other slow-conducting substances used in the fireplaces for burning it. The use of smokeless coal had also been extended in the metropolis; but the Council found that the description of such coal supplied was in a large number of instances unsuitable or inferior, and from that cause, coupled with the fact that smokeless coals were not generally supplied by coal merchants, there had not been, so far, any very marked increase in its consumption. Marked improvement had, however, been made in open grates and stoves for burning that description of coal, and one firm of manufacturers, who brought out a cheap stove at the South Kensington Exhibition, had sold upwards of 14,000 during the past two years; and they remarked that the public seemed ready to burn non-smoky coal if proper stoves for using it were offered at a reasonable price. Appliances for improving the draught of chimneys had also been introduced lately, and that tended to facilitate the use of smokeless coal. The Council had examined the present state of the administration of the law for the suppression of smoke, and they considered that in view of the enormous extension of buildings and factories in London and large towns, and in view also of the evidence that smoke could be to a great extent, if not entirely, avoided, the scope of legislative enactments for abating smoke should be extended and their provisions duly enforced.

One part of the Report deals with a matter to which we attach the greatest importance. It is suggested that there should be some place which the public can visit and where they may examine any apparatus that is approved of, or which they may wish to purchase; but above this it is pointed out that a place is requisite where scientific, chemical, and other tests may be made for the information of the public generally, but especially for the help of inventors and manufacturers who may wish to try new suggestions. The Report also suggests that in connection with this there should be some place for discussion and public lectures, for the general advancement and diffusion of knowledge touching smoke abatement. The third proposal is certainly the most doubtful one, but the

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[1] The piece of apparatus now exhibited, illustrated the collisions taking place between the molecules of gaseous matter, and the diffusion of one gas into another. It consisted of a board of about one metre square, perforated with 100 holes in ten rows of ten holes each. From each hole was suspended a cord five metres long. To the lower end of each cord in five contiguous rows, there was secured a blue coloured glass ball of four centimetres diameter; and similarly to each cord of the other five rows, a red coloured ball of the same size. A ball from one of the outer rows was pulled aside, and, being set free, it plunged in amongst the others, causing collisions throughout the whole plane in which the suspended balls were situated.

[2] *Sitzungsberichte* of the Vienna Academy, Oct. 12, 1865, p. 395.

[3] Or say a globe of 16 centimetres diameter.